Progress Report

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STUDY ON SUBSTRATE REFRACTIVE INDEX SENSITIVITY OF MULTILAYER ANTIREFLECTION COATING DESIGN

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1. Anti-Reflection Coatings

Antireflection coatings (AR) are used to reduce the Fresnel reflectance of optical components. In imaging systems, AR coatings improve the efficiency because they provide less light lost. In complex optical systems, the reduction in reflections also improves the contrast of the image by elimination of stray light.

1.1. Basic Principles

The basic idea behind Anti reflection Coatings (ARCs) is interference of light. When a thin film of transparent material rests on a much thicker material, incident light on this arrangement undergoes two external reflections: one at the surface of the film, and another at the boundary of the film and substrate. This is depicted in Figure 1. The light beam that traverses the film eventually recombines with the beam which was reflected from the film surface; however, due to the difference in path length, a phase difference arises between the two beams. In the case of normal incidence, the second beam travels an extra optical distance of twice the thickness of the film times its refractive index:

$$\Delta = 2n_1 t$$

If this optical path difference is equal to one wavelength of the (monochromatic) light, the interfering beams find themselves in phase and the light is perfectly reflected. On the other hand, if the optical path difference is equal to half the wavelength, the beams interfere destructively. Mathematically

$$\Delta = 2n_1 t = \frac{\lambda_0}{2}$$

$$t = \frac{\lambda_0}{4n_1}$$

The thickness of the film to be used thus depends on its refractive index. In order to achieve maximum destructive interference, the coefficients for the external reflections must be equal. The reflection coefficient at the film surface can be written as

$$r_1 = \frac{n_1 - n_0}{n_1 + n_0} = \frac{1 - \frac{n_0}{n_1}}{1 + \frac{n_0}{n_1}}$$

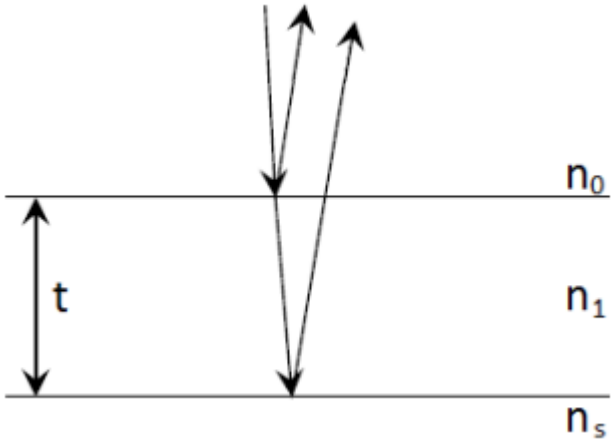

Figure 1: External reflection at the surface of the film and the film/substrate boundary

Now at the film/substrate boundary:

$$r_2 = \frac{n_s - n_1}{n_s + n_1} = \frac{1 - \frac{n_1}{n_s}}{1 + \frac{n_1}{n_s}}$$

These can only be equal if the ratios between the refractive indices are equal, i.e. if

$$\frac{n_0}{n_1} = \frac{n_1}{n_s}$$

$$n_1 = \sqrt{n_0 n_s}$$

If the incident medium is taken to be air (as it often is) so that $n_0 = 1$, then for maximum destructive interference the refractive index of the film is simply the square root of the refractive index of the substrate. While this analysis is valid, it comes with several caveats. Firstly, it only considers normally incident light; for non-normal incidence, the transmission angle plays a role in determining film thickness and must be determined using Snell's law. Secondly, this analysis neglects dispersion and so is only valid at one wavelength or a small range of wavelengths. Also important is the fact that materials with

refractive indices that agree with this geometrical result are not usually available. As such, it is necessary to resort to other means in order to be able to determine reflection from thin films under different scenarios

2. Literature Survey:

1. **Kirill Isakov et al. (2020)** work presents a superhydrophobic antireflective (AR) coating on glass. The coating consists of a grass-like alumina layer capped with plasma-deposited fluoropolymer. The grass-like alumina is formed by hot water treatment of atomic layer-deposited alumina on glass, and the fluoropolymer is plasmadeposited from CHF3. Excellent broadband AR performance is observed in the visible spectrum with an average transmission of 94.9% for single-sided coated glass, which is close to the maximum 95.3% possible for this glass. Extremely desirable contact angles are obtained with 5−7 min-long fluoropolymer treatments on grasslike alumina with 173° advancing and 160° receding contact angles. This type of multifunctional coating can be beneficial in a multitude of applications like self-cleaning AR coating for solar panels, windows in high-rise buildings, sensors, and aerospace applications as well as just utilizing the excellent water repellent behavior in applications where only superhydrophobicity is required.
2. **Jihua Zhang et al. (2020)** reported that the metasurfaces have been widely used to control beam propagation e.g. transmission, reflection, and absorption on an interface through a thin layer of nanoantennas with the thickness smaller than the wavelength. However, previous study of metasurfaces typically focused on controlling only one form of these propagations. In this work, we propose and demonstrate a multipolar plasmonic metasurface that can simultaneously realize antireflection (AR) and antitransmission (AT) in the visible and nearinfrared regions. The AR and AT arise from destructive multipolar interferences in the backward and forward directions, respectively, i.e., through the generalized Kerker effect. By engineering the multipolar interference, we show that the AR and AT can happen at different or similar wavelength ranges, which can be used for low-absorption spectral filters due to off-resonance operation or inversely strong optical absorbers through near-resonance operation, respectively. We also present a simple t dimensional design of the multipolar metasurface that supports AT for one polarization and AR for another polarization over a broadband, which is applicable to broadband transmissive polarizers with efficiency over 90% and the extinction ratio over 18 dB. By tuning the dimension and thus the multipolar interference, the transmitted polarization and operation wavelength are both controllable.
3. **V. Pacheco-Pena et al. (2020)** explains that antireflection is complete transmission of waves through the interface between two different media can be achieved by proper impedance matching between them. One of the most common techniques for

such reflectionless propagation is the quarter-wave impedance transformer, where an additional slab of material with proper material parameters and carefully engineered dimensions is added between the two media, minimizing reflections. Metamaterials, with properly designed spatial inhomogeneity, have exhibited unprecedented ability to tailor and manipulate waves, and recently temporal metamaterials have also gained much attention, enabling spatiotemporal control of wave propagation. Here a temporal analogue of the quarter-wave impedance transformer technique, which we name "antireflection temporal coating," is proposed using time-dependent materials. The proposed technique is demonstrated, analytically and numerically, using metamaterials with a time-dependent permittivity. Comparison with the conventional (spatial) impedance-matching technique is shown, demonstrating that both impedance matching and frequency conversion are achieved with our proposed temporal version. As an illustrative example, the present technique is also applied to match two waveguides with different cross sections, demonstrating an example of scenarios where it may be applied.

4. **Hirohisa Uchida et. al. (2019)** realized practical antireflection (AR) coatings for organic nonlinear optical crystals via dip coating of soft materials; specifically,the amorphous fluoropolymer Cytop. 4-N, N-dimethylamino-40-N0-methyl-stilbazolium tosylate (DAST) crystals were coated with a Cytop solution; the coating thickness was controlled by the Cytop solution concentration. The Cytop coating did not show evidence of cracking or peeling after 200 days. The transmittance of AR-coated DAST crystals using a 5% Cytop solution was 90.9% at 1560 nm, an improvement of 17.8% compared to that before coating. High repeatability of the improvement was also confirmed. Moreover, the AR-coated DAST crystal was confirmed to have a stable transmittance over 720 minutes against the irradiation of a femtosecond laser with a power density of 3.6 GW/cm2. The ability to coat organic nonlinear optical crystals with an AR layer using soft materials is expected to have a wide range ofoptical applications.

5. **Alexandr Belosludtsev et. al. (2019)** introduced an investigation of aluminum oxynitride films deposition using one metallic target in various gas mixture. The optimized preparation conditions for such reactive sputtering were found. Non-optimized conditions led to sputtering target poisoning or under-stoichiometric films formation. The reactive deposition process was guided by the active feedback control system. Dependence between gas composition and changes of nitrogen concentration in the films and their optical properties were investigated. The increase of nitrogen content in films leads to increases in extinction coefficient in UV region and refractive index in the whole investigated wavelength range. It was shown the possibility of using oxynitride films for antireflective coating (AR) deposition. The coating composed from three layer of oxynitrides with changing the composition. It has low surface roughness and low compressive stress.

6. **N. El-Mahallawy et al. (2018)** reported that research has adopted lately the improvement of solar collectors' efficiency and durability by coating its surface with special selective coatings. The selectivity of any coat is governed by the ratio between the absorptivity of this coat in the UVrange to its emissivity in the IR range (named selectivity). There emerged a need of using simulation software to estimate the effect of different elements and compounds on the optical properties before getting into experimental analysis. Several research has discussed the stability and durability of the coats under high temperature conditions since it was proved that the coat efficiency increases at high temperature; i.e. being more selective. This research has approached the simulation of different metal(M) / metal oxide (MOx) based tandems in order to obtain promising selective properties that can be taken into further experimental investigation. Five metals and six metal oxides were chosen based on previous literature to be simulated using OpenFilters open source software and results were analyzed. Oxides of tungsten, copper and silicon have shown superior selective results through different layering techniques than others.
7. **T. Tolenis et. al. (2017)** reported that achieving higher optical power in UV laser systems is a challenging task due to the limited performance of their built-in optical elements. As a rule of thumb, interference coatings of such elements are found to be the weakest links by the means of laser-induced damage threshold (LIDT). The optical resistance is directly attributed to the fundamental absorption properties of deposited layers. Unfortunately, there are only a limited set of available materials with discrete refractive indices that are also compatible with UV applications. In this study, an attempt is made to employ sculptured layers in order to produce durable anti-reflective (AR) coatings by using the so-called glancing angle deposition (GLAD) method. Spectral, structural, mechanical and stress properties of GLAD coatings were investigated in detail. AR coatings produced by GLAD were found to be three times more laser damage resistant at 355 nm wavelength as compared tothose prepared by ion beam sputtering (IBS).
8. **Neelam Kumari et. al. (2015)** reported that broadband Multilayer Antireflection (AR) coatings markedly improve the transmission efficiency of any optical component such as lens, prism, beam-splitter, beam combiner or a window. By reducing surface reflections over a wide wavelength range, broadband antireflection coatings improve transmission and enhance contrast which is desired in avionic displays. The broadband antireflection coating consisting of MgF_2, ZrO_2 and Al_2O_3 were designed to cover the whole visible spectrum and fabricated on optical grade glass substrate. The optical characterization of these coatings indicates reduction of the reflection to 2.28% as compared to 8.5 % at 545 nm (i.e. design wavelength of most avionic displays) for bare substrate making them useful in optical displays for avionic applications.

9. **K.H. Nielsen et. al. (2014)** reported on the direct consequences of reversible water adsorption on the optical performance of silica-based nanoporous antireflective (AR) coatings as they are applied on glass in photovoltaic and solar thermal energy conversion systems. In situ UV-VIS transmission spectroscopy and path length measurements through high-resolution interferometric microscopy were conducted on model films during exposure to different levels of humidity and temperature. We show that water adsorption in the pores of the film results in a notable increase of the effective refractive index of the coating. As a consequence, the AR effect is strongly reduced. The temperature regime in which the major part of the water can be driven-out rapidly lies in the range of 556C and 1356C. Such thermal desorption was found to increase the overall transmission of a coated glass by , 1%-point. As the activation energy of isothermal desorption, we find a value of about 18 kJ/mol. Within the experimental range of our data, the sorption and desorption process is fully reversible, resulting in optical breathing of the film. NanoporousARfilms with closed pore structure or high hydrophobicity may be of advantage for maintaining AR performance under air exposure.

10. **Khalid H. Abass et. al. (2012)** reported that Al-Ni-Cr alloy ingots contains 0.25, 0.5, 0.99, 1.98 at.% of Ni-Cr were prepared by melting together of high purity wire aluminium , powder of nickel and very small pieces of chromium in an electric furnace at 800^{o}C under a pure argon atmosphere. Specimens Al and Al-Ni-Cr alloys were annealed at 560^{o}C for 1300 hr, and rapid quenched in water. Nanofilms prepared with thicknesses 8, 15, 25 nm of Al and Al-Ni-Cr alloys were deposited by thermal evaporation technique under vacuum of 10-5 mbar onto glass substrate temperature 298 K and rate of deposition 0.2 nm/sec. The crystallite size of such nanofilms were measured using AFM images and found to be ranged of 4.754 -10.204 nm and roughness ranged of 0.538-2.65nm. The measured transmittance values increases with decreasing thickness with the range of 90-94% at 8 nm. The optical band gaps calculated decreases with increasing concentration of Ni-Cr.

11. **Liu et al. (2010)** studied about Laser Resistance of Ta_2O_5/SiO_2 and ZrO_2/SiO_2 Optical Coatings under 2 μm Femtosecond Pulsed Irradiation. Ta_2O_5/SiO_2 and ZrO_2/SiO_2 high reflecting (HR) coatings are prepared by ion beam sputtering and electron beam evaporation, respectively. The laser-induced damage thresholds (LIDTs) of these samples are investigated with 2 μm femtosecond pulse lasers (80 fs, 1 kHz). It is found that the Ta_2O_5/SiO_2 HR coating has a higher capability of laser damage resistance than the ZrO_2/SiO_2 HR coating in the 2 μm femtosecond regime. The scanning electron microscope results show that the damage sites of the ZrO_2/SiO_2 HR coating have a relatively porous structure, the loose structure of coatings will provide more sites for water molecules, and the LIDTs of HR coatings will be reduced as a result of the strong water absorption at the wavelength of 2 μm.

12. **Ozlem Duyar et al. (2008)** studied about Optimization of TiO_2 films prepared by reactive electron beam evaporation of Ti_3O_5. In this paper, we report the development of TiO_2 films by reactive electron beam evaporation, using a recently introduced Ti_3O_5 material as the starting material. During experiments, considerable effort was undertaken to optimize the deposition conditions for preparation of high quality TiO_2 films. The processing window for preparation of high quality stoichiometric TiO_2 was found to be quite narrow. The refractive index at 550 nm was approximately 2.41 for the samples. Combinations of spectroscopic ellipsometry and transmittance or reflectance spectrophotometry were used to measure and characterize the optical properties of the films. The surface morphology and microstructure were investigated by using atomic force microscopy and field emission scanning electron microscopy, respectively. The hardness and Young's modulus were calculated to be approximately 12 and 138 GPa by the nanoindentation measurements.

13. **A. H. Jareeze (2008)** designed and simulated antireflection coatings, optical reflection values deduced with a matrix formulation via computer program was written in matlab (Ver.7), a five materials were selected to reduce reflection from the surface of glass optical system which is using in single , double and triple frequency of laser Nd-YAG . The results show, In single layer antireflection coating, the reflection have been reduced but only one or two minima reflection, In double layer antireflection coating, two zero reflection were found at wavelengths of the laser Nd-YAG, In three layer antireflection coating the best results were found, two minima reflection were found at (532,1064 nm) and zero reflection at (355 nm) it is agreement with condition design.

14. **A Kasikov et al. (2006)** analyzed refractive index gradients in TiO2 thin films grown by atomic layer deposition. Transmission spectra of TiO2 films grown by atomic layer deposition on fused silica by using Lorentz dispersion and a model consisting of two sublayers inside a film. It has been shown that the deposition process parameters significantly influenced the refractive index gradient in the film growth direction. The films grown at a lower flow of the carrier gas showed a 35 nm thick sublayer with low refractive index at the silica substrate and a layer with a higher refractive index at the film surface. The films deposited at higher carrier gas flow had a higher refractive index at the substrate and a lower refractive index at the film surface. The results also demonstrate that by using a parameter modelling one can obtain some information about the internal structure of a film even if there are no clearly defined interference fringes in a transmission spectrum.
15. **H. Ganesha Shanbhogue et al. (1997)** studied about Multilayer antireflection coatings for the visible and near-infrared regions. With a high-refractive-index mixed-oxide dielectric material of $ZrTiO_4$ and ZrO_2 in combination with magnesium flouride MgF2, design optimization and experimental production of low-loss

antireflection coatings are carried out. Design-optimization studies that make use of these materials as constituents of a seven-layer coating system demonstrate that when the useful bandwidth of an AR coating is extended to cover a wider spectral range, the designs are in general found to have increased integrated reflection loss, higher ripple, and increased spectral instability. The experimental studies on Sub2 material show that the films have excellent optical performance over a wider process window, the advantage of which is demonstrated in the production of different AR coatings on a variety of glasses with refractive indices that range from 1.45 to 1.784 and different mechanical, thermal, and chemical properties. The manufacturing process of AR coatings shows a consistency better than 99% with respect to optical properties and durability.

16. **J. A. Dobrowolski et al. (1996)** reported that It is possible to design normal-incidence antireflection coatings that reduce the reflectance of any substrate with a refractive index that lies in the range of 1.48 to 1.75. The performance of such coatings depends on the width of the spectral region over which the reflectance is to be suppressed, on the coating materials used for their construction, and on the overall optical thickness of the layer system. For example, the calculated average spectral reflectance of a set of six different substrates with refractive indices 1.48, 1.55, 1.60, 1.65, 1.70, and 1.75, when coated with a 0.56-mm-thick, eight-layer antireflection coating designed for the 0.40–0.80-mm spectral region, was 0.34%. This is higher than the average reflectance that is attainable with a conventional antireflection coating of similar optical thicknesses designed for a particular refractive index. However, it is an acceptable value for most applications. With the universal type of antireflection coating described, it is thus possible to coat a number of different refractive-index substrates in one deposition run, and this can result in considerable cost and time savings.
17. **Li Li et al. (1992)** studied about Antireflection coatings for both visible and far-infrared spectral regions. Two methods are described for the design of antireflection coatings that act in two widely separated spectral regions. Design results are presented for coatings on ZnS, ZnSe, and Ge substrates that reduce the reflectance in a broad region at 10 plm, as well as in a band of wavelengths in the visible or near-infrared part of the spectrum. It has been shown theoretically and experimentally that it is possible to construct AR coatings on infrared substrate materials that operate in widely separated spectral regions. Fairly wide AR regions in the visible and in the infrared can also be achieved simultaneously. This improves the chances of a successful manufacture of the coating. The use of these more complex designs does not materially affect the overall deposition time and therefore should not substantially increase the cost of infrared AR coatings.
18. **C. L. Nagendra et al. (1985)** reported design and optimization of low-loss wideband antireflection coatings for the visible and infrared regions: a new method. A new

method for design of multilayer antireflection coatings (ARCs) which makes use of a specified reflectance value R, either zero or nonzero at a particular wavelength , is developed. It offers an explicit scheme for evaluation of the optical/geometrical thickness of each layer, and the design variables are opti-mized with respect to integrated reflection loss R* over a specified bandwidth. It has been found that the method can be applied for design of wideband ARCs useful in the visible and IR regions, and the resulting bandwidth and residual reflection losses can be controlled as a function of Ro. The method is found to be comprehensive so that more useful designs can be worked out, and it can be directly adapted to the design of single- and double-layer ARCs.

19. **A. H. Madjid et al. (1980)** developed the theory of very thin, nonideal multilayer stacks, and the computed wavelengthvariation of the transmissivity and reflectivity is compared with that measured on experimentally prepared silver-silicon monoxide layer stacks. The model imputes a step-function character to the complex index of refraction along the layer structure, and nonideality is accounted for by allowing for the likely presence of interfacial layers between each primary layer pair and also for the possibility that the thickness of the individuallayers may vary randomly within some limit of error. Abeles's transfer matrix technique is usedto arrive at the characteristic matrix of the stack, and additive corrective matrices are derived to account forthe effects due to interfacial layers and the random layer thickness variation.
20. **M. Sparks et al. (1979)** studied about Simplified description of multilayer dielectric reflectors. The spectral-absorptance curves of quarter-wave reflectors are quite asymmetric in general as a result of absorption in the layers. The maximum electric field E in an infinite stack is in the center of the high-index (low-index) layer at the low-frequency (high-frequency) end of the high-reflection band. Thus, the absorptance minimum of a stack having much greater absorption in the high-index material occurs at c > &c, (band center). Operation at $\omega > \omega_c$ could increase the damage resistance if the high-index material is easily damaged. At c,, E decays rapidly. As a) departs from w, in an infinite reflector, E penetrates deeper into the coating, with no decay at the band edges. The peak-to-peak distance in an infinite dielectric stack is constant for all frequencies in the band. By using the continuity of E and d E Id z, E can be obtained from E = 0 at the metallic substrate or, in an infinite stack, from E = 0 at the reflector surface for $\omega = \omega_c$, or E = 0 in the center of the high- or low-index layer at the band edges. Simple closed-form approximations for the spectral absorptance and the phase of E are accurate and sufficient for present applications.
21. **K. N. Chopra et al. (1979)** Double-layer quarter-half AR coatings effective at two wavelengths simultaneously in the visible region have been fabricated by depositing

a homogeneous ZnS-MgF_2 mixture as the inner layer and MgF_2 as the outer layer. The results obtained agree well with those predicted theoretically.

22. **M. Sparks (1977)** reported simple method of calculating the reflectance *R,* absorptance from the substrate, absorptance from arbitrarily distributed losses in the coating material or interfaces, and the phase distortion resulting from small wavelength changes, from heating, and from deviations in the thicknesses and indices of all or any one or more of the layers is given for normal-incidence multilayer-dielectric reflectors with 1 - *R '4* 1. The method is employed to derive useful expressions for absorptance, reflectance, and phase distortion that are not easily obtained by other methods. The key is the use of the simple zeroth-order *(R* = 1) electric field distribution in the coating (sinusoidal standing wave whose amplitude is reduced by a factor ***no/nH*** at the coating surface and by a factor of nL/nH at every *LH* interface, and is unchanged at every *HL* interface) to obtain first-order results.
23. **J.E. Rudisill et. al. (1974)** reported the development of surface finishing and coating technology at 10.6 Am for polycrystalline ZnSe laser windows is presented. Optical evaluation of the coated windows shows that the 10.6-Am absorption and reflection can be held to less than 0.1% per surface. Surface finishing procedures, theoretical coating designs, and recent experimental results for antireflection coatings for ZnSe are presented.
24. **J. T. Cox et al. (1962)** Triple-layer antireflection coatings on glass (n~1.5) can provide a broader region of low reflectance than single- or double-layer coatings. Of the possible triple-layer combinations, the quarter-half-quarter construction has been found to be most suitable for the visible and near infrared. Calculations of reflectance as a function of wavelength have been carried out for many combinations of indices and for thickness variations. The effectiveness of the coatings is not much affected by small thickness variations of the two inner layers but does depend quite strongly on the thickness of the outer layer. Reflectance curves for various angles of incidence have been calculated for coatings matched both at normal incidence and at various given angles of incidence. Durable coatings have been prepared which have a single-surface reflectance of less than 1% from 415 to 840 μm, with a corresponding range for the near infrared. The materials which have been used in the preparation of these coatings are: outside layer, MgF_2; middle layer, SiO, ZrO_2, ZnS, CeO_2 , and Nd_2O_3; inside layer, CeF_3 and SiO.

25. **J. T. Cox et. al. (1961)** developed vacuum-deposited single-, double-, and triple-layer infrared antireflection coatings for Si, Ge, InAs, and InSb for the **1- μ** to **15-μ,** region. MgF 2, didymium fluoride, SiO, ZnS, CeO_2, and Si were used for the preparation of the coatings. All of the coatings are hard and durable and can be cleanedand boiled in water for several hours with little or no damage. With these coatings,the transmittance of Si and Ge plates can be increased to a maximum value of nearly 100%, and stays above 90% over a wavelength interval the limits of which

are in the ratio of 1.5:1, 2.7:1, and 3:1 for single-, double,- and triplelayer coatings, respectively. InAs and InSb are slightly absorbing, but more than 90% transmittance can be obtained with sufficiently thin antireflected plates. The temperature dependence of absorption in all four of these materials has been measured in the range from 25 0C to 250'C.

26. **L. A. Catalan (1961)** reported optical properties of two-layer antireflection systems are discussed. Theory is applied to study the optical performance of bismuth-oxide/magnesium-fluoride bilayers. The theoretical study includes graphs and numerical tables showing the spectral reflectances for different glass substrates, the effect of film-thickness mismatching and the spectral reflectance for plane-polarized incident light.
27. **P. H. Berning *(*1961)** reported the behavior of a symmetrical nonabsorbing multilayer in the region where the component film thicknesses are small compared with the wavelength closely approximates the behavior of a homogeneous single film. The index of the equivalent film can be made to take any value intermediate to the index values of the constituent films; and by adding together multiple periods of the basic combination, the equivalent thickness can be made as large as desired. Such combinations are shown to have useful application in the construction of wide-range antireflection coatings for high-index infrared optical materials.

28. **J. T. Cox et al. (1958)** made very hard and durable single layer antireflection coatings for Ge and Si which result in a peak transmittance of better than 98% at any desired wavelength in the infrared up to about 15,u. Silicon monoxide makes an excellent antireflection coating for silicon and germanium in the near infrared, but cannot be used in the 10-1μ **r**egion where it becomes strongly absorbing. Zinc sulfide has been found to be the most suitable antirefiecting material at the longer wavelengths. Under proper conditions zinc sulfide films, which in the past have frequently exhibited unsatisfactory durability, can be prepared as very hard and adherent antireflection coatings for germanium and silicon. The best zinc sulfide films are obtained when the substrate is heated to about 150'C and cleaned with a dc glow discharge just before the evaporation is made. The coatings can stand several hours boiling and several days immersion in water without damage and have been used for periods up to one year without showing any deterioration.

3. Material Selection:

Combination of materials to be selected for desired effective index generation in wavelength range of spectrum. Available normal and stable coating materials for visible region:

Low index materials: MgF_2, SiO_2, Al_2O_3… etc.

High index materials:, Ta_2O_5, HfO_2 , TiO_2… etc.

Starting with easily evaporating materials by thermal sources (YF_2, ZnO, SnO_2 etc) and it will be explained with other typical materials like oxides etc.

In the above listed material TiO2 is used as high index material and MgF2 is selected as Low index material. According to Dobrowolski [16] TiO2 and MgF2 both gives a good antireflective coating with wide band range but as we selected that to reduce the cost of production multi-substrate coating must be designed. This can be fulfill with these two materials having multi-layer coating. Dobrowolski [16] designed with greater than 23 layers design for the visible range with ZnS and MgF2 materials. Our target is to design with lesser number of layer by replacing ZnS with TiO2, which is again more advantageous giving a more stable index of refraction.

4. References

1. K. Isakov, C. Kauppinen, S. Franssila, and H. Lipsanen, Super hydrophobic Antireflection Coating on Glass Using Grass-like Alumina and Fluoropolymer, ACS Appl. Mater. Interfaces, **12** (2020) 49957.
2. J. Zhang, R. Wei and C. Guo, Simultaneous implementation of antireflection and antitransmission through multipolar interference in plasmonic metasurfaces and applications in optical absorbers and broadband polarizers, Nanophotonics, **9** (2020) 4529.
3. V. Pacheco-Pena and N. Engheta, Antireflection temporal coatings, Optica, **7** (2020) 323.
4. H. Uchida, C. Koyama, T. Takagi, P. Wang, T. Kamei, K. Kawase, and K. Takeya, Antireflection coating on organic nonlinear optical crystals using soft materials, Appl. Phys. Lett., **115** (2019) 231107.
5. A. Belosludtsev et. al., Design, preparation and characterization of antireflective coatings using oxynitride films, Optical Materials 98 (2019) 109430.
6. N. El-Mahallawy, M. R.A. Atia, A. Khaled, M. Shoeib, "Design and simulation of different multilayer solar selective coatings for solar thermal applications", Materials Research Express (2018).
7. T. Tolenis, L. Grineviciute , R. Buzelis, L.Smalakys, E. Pupka, S.Melnikas, A. Selskis, R. Drazdys, and Andrius, Sculptured anti-reflection coatings for high power lasers, Optical Materials Express, **7** (2017)1249
8. N. Kumari, M. Kumar, P K Raoa , V. Karara, A. L. Sharmaa, Broadband Antireflection Coatings for Multifunctional Avionic Displays", International Conference on Optics and Photonics 2015.
9. K. H. Nielsen, T. Kittel, K. Wondraczek & L. Wondraczek, Optical breathing of nano-porous antireflective coatings through adsorption and desorption of water, Scientific Reports **4** (2014) 6595.

10. K. H. Abass and F. Sh. Hashim, Novel Preparation of Antireflection Nanofilms from Al-Ni-Cr Alloy, British Journal of Science **7** (2012) 1.

11. L. Na, W.Ying-Jian, Z.Ming, J. Xu-Feng, W. Yan-Zhi, C.Yun, J. Yun-Xia, Laser Resistance of Ta_2O_5/SiO_2 and ZrO_2/SiO_2 Optical Coatings under 2 μm Femtosecond Pulsed Irradiation, CHIN. PHYS. LETT. 27 (7) (2010) 074215.

12. O. Duyar, F. Placido and H Zafer Durusoy, Optimization of TiO_2 films prepared by reactive electron beam evaporation of Ti_3O_5, J. Phys. D: Appl. Phys. 41 (2008) 095307

13. A.H. Jareeze, Design And Simulation Antireflection Coating For Laser Nd:Yag (1064nm) Wavelength And Has Multifrequency (532,355nm) On Glass Substrate, Journal of Al-Nahrain University, **11**(2) (2008)104-111.

14. A Kasikov, J Aarik, H Mandar, M Moppel, M Pars and T Uustare, "Refractive index gradients in TiO_2 thin films grown by atomic layer deposition", J. Phys. D: Appl. Phys., 39 (2006) 54–60.

15. H. Ganesha Shanbhogue, C. L. Nagendra, M. N. Annapurna, S. Ajith Kumar, and G. K. M. Thutupalli, Multilayer antireflection coatings for the visible and near-infrared regions, Applied Optics **36** (25) 1997.

16. J. A. Dobrowolski and B. T. Sullivan**,** Universal antireflection coatings for substrates for the visible spectral region, Applied Optics **35** 1996.

17. Li Li, J. A. Dobrowolski, J. D. Sankey, and J. R. Wimperis, Antireflection coatings for both visible and far-infrared spectral regions, Applied Optics **31**(28) 1992.

18. C. L. Nagendra, M. Viswanathan, and G. K. M. Thutupalli, Design and optimization of low-loss wideband antireflection coatings for the visible and infrared regions: a new method, Applied Optics **24** (8) 1985.

19. A. H. Madjid and A. J. Abu El-Haija, Optical properties of very thin, nonideal multilayer superlattice stacks, Applied Optics **19** (15) (1980).

20. M. Sparks, M. Flannery, "Simplified description of multilayer dielectric reflectors", J. Opt. Soc. Am., **69** (7) 1979.

21. K. N. Chopra, 0. P. Grover, and R. Hradaynath, Antireflection coatings effective at two wavelengths simultaneously in the visible region using homogeneously mixed dielectrics, Applied Optics, **18** (1979) 1750.

22. M. Sparks, A simple method for calculating the optical properties of multilayer-dielectric reflectors, **J.** Opt. Soc. Am., **67** 1977.

23. J. E. Rudisill, M. Braunstein, and A. 1. Braunstein, Optical Coatings for High Energy ZnSe Laser Windows, Applied Optics **13**, 9 1974.

24. J. T. Cox and G. HASS, Triple-Layer Antireflection Coatings on Glass for the Visible and Near Infrared, Journal Of The Optical Society Of America, **52**(9) 1962**.**

25. J. T. Cox, G. Hass and G. F. JACOBUS, Infrared Filters of Antireflected Si, Ge, InAs, and InSb, J. Optical Society America, **48** (1958) 677.

26. L. A. Catalan, Some Computed Optical Properties of Antireflection Coatings, Journal of The Optical Society Of America, **52** (4) 1962.

27. Peter H. Berning , Use of Equivalent Films in the Design of Infrared Multilayer Antireflection Coatings journal of the optical society of america **52**, 4, 1961

28. J. T. Cox and G. Hass, Antireflection Coatings for Germanium and Silicon in the Infrared, Journal of The Optical Of Society America **48** 10 (1958)